CONCRETE CURING
WITH
HUNT PROCESS

CONCRETE CURING DATA

Compiled from an Investigation of Bituminous Curing Conducted by The Civil Engineering Testing Laboratories of Columbia University

INTRODUCTION

IT is universally conceded that adequate curing is essential to develop to the fullest extent the various properties of concrete. This is especially true in highway construction, and other thin slabs. The development of strength and resistance to wear are seriously retarded, and other properties are adversely affected by the lack of, or improper and inadequate, curing. Investigations made by various organizations have demonstrated conclusively the importance of curing where water tightness, surface strength and resistance to abrasion, or wear, are desired.

In the construction of highways, piers, walls, and other concrete structures having exposed surfaces, the major loss of desirable physical properties resulting from ineffective curing methods is confined to the material adjacent to the surface. Yet it is at the surface that the concrete is expected to provide resistance to wear and weathering agencies. Whatever the other causes of deterioration of concrete may be, the surface effects of inadequate curing are a major contributing cause.

Generally the effectiveness of curing treatments is determined by the resultant compressive strength of cores taken from the structure or of standard cylinders because of the known relationship of the compressive strength of concrete to its other physical properties. At the best, these tests can give only a partial measure of the effects of lack of curing.

The problem of curing is to provide treatments such that sufficient mixing or free water will be retained to supply the continued hydration demands of the cement in setting. After initial hardening, loss of water occurs by evaporation from the exposed surfaces. The fracture of a partially dried mass of concrete will reveal moisture in the central part although the edges appear dry.

Where cores are taken from a highway, or in the laboratory, where test cylinders are left in metal molds with only the top surface exposed, evaporation occurs only from this surface, and its effects are most pronounced in the material immediately adjacent to the surface. In fact, the test cylinder may be considered as composed of concrete with a cap of weaker material at the top, the depth of this cap depending upon the rate of evaporation.

Some Facts Regarding Concrete Curing

The two most essential requirements of concrete, whether in a highway slab or a structure, are strength and durability—strength to carry the designed load, and durability to resist exposure to the elements. Without these two characteristics, concrete is neither economical nor satisfactory. Presupposing that concrete is properly designed, mixed and placed, both strength and durability are largely dependent on proper curing.

Concrete "sets" because of chemical reactions between the cement and water. The hardening process continues indefinitely, providing the temperatures are favorable and there is sufficient moisture retained in the mix to complete the hydration. With the tendency towards dry concrete mixes, it becomes increasingly important to retain all the mixing water until complete hydration has taken place.

The ultimate strength and durability of concrete are dependent on two factors—age and curing conditions. Under practical job conditions it is generally impossible to cure for long periods or take advantage of the aging factor; therefore, it is essential that an efficient curing medium be applied as soon as possible after the concrete has been deposited and finished. At the best, a curing medium serves only one purpose—it waterproofs and prevents evaporation of the mixing water until it has had an opportunity to combine with, or hydrate, the cement.

Although concrete continues to increase in strength for a long period, the increase is most marked during the first few weeks. Fully eighty (80%) percent of the ultimate strength is attained by the end of twenty-eight (28) days, while from then on, the rate of increase is relatively slow. For this reason alone immediate and efficient curing is indicated.

First Twenty-four Hours Critical Curing Period

Most authorities agree that the greatest loss by evaporation occurs during the first twenty-four (24) to thirty-six (36) hours, and that the type of protection (curing) given during that period has a decided effect on the potential strength and durability of the concrete. The treatment applied during the first twenty-four hours has a marked effect on the future strength, density and durability of the concrete mass. This is especially true of the portion near the surface.

Evaporation Causes Extreme Losses in Surface of Slab

Recent investigations, made by the Columbia University Testing Laboratory demonstrate that the loss in strength in the upper section, or strata, of a slab of concrete, due to evaporation, is forty to fifty percent of that developed in the lower portion, which is not subjected to the same rapid drying conditions.

One Application (directly behind the finishers); the Curing Is Completed and Evaporation Stopped

Complete Hydration of Cement Is Assured by Adequate Curing

There is no question that curing very materially increases the compressive strength of concrete, but its effect on other properties is probably of even greater importance. Thorough and adequate curing is one of the most important elements in the production of water tight and dense concrete, Building up the internal structure, by giving an opportunity for complete hydration, brings out to a full extent all of the inherent qualities of a concrete mass.

Curing Increases Skin Strength

Increase in skin strength or resistance to abrasion is assured by adequate curing. This is especially important on pavements, floors, sidewalks, and other surfaces subjected to wear. Proper curing, which renders active all the free water in the mix, particularly during the early stages of the hydration, aids in securing a hard, dense surface, and prevents hair checking and scaling. The curing medium, in order to obtain its fullest effect, should be applied soon enough to prevent any surface drying, and before any checking or marked dehydration has started to occur.

Free Water

Practically all concrete contains an excess of free water, or more than is theoretically required for hydration. The problem of curing is, therefore, to prevent the evaporation of the water. This is particularly true of the early stages, or the first few days.

Concrete structures that are intended to be water tight have always presented a problem. It is essential that the surface be sealed and all the mixing water retained, in order to attain maximum density.

Dry Concrete Must Be Protected

The curing concrete blocks, tile and other cement products should not be neglected. The mixture for this class of concrete must be so dry that, when the mold is removed, immediately after the tamping proccess, the concrete will retain its shape. In such products, the water content is necessarily so low that any loss by evaporation is very detrimental.

Reduction of Shrinkage

It is a well known fact that a concrete mass changes volume with varying conditions of exposure. Shrinkage begins at the time the concrete is deposited, and continues for a period of months when exposed to dry air. This volume change should be reduced to a minimum as a prevention of surface checking and the development of internal stresses caused by undue amounts of shrinkage and expansion. The fundamental cause of shrinkage is the loss of water by evaporation from the surface. Shrinkage really takes place in two stages; the first, while the concrete is a plastic mass, and the second, after the initial set and during the period of hardening. Shrinkage during the first period is rapid, the rate depending upon the amount of evaporation, which in turn is dependent upon the type of protection (if any) the concrete surface receives. In a thin section or slab of concrete, such as a highway, floor slab or sidewalk, exposed to dry air, with no protection, an abnormal amount of shrinkage in the early stages will inevitably result in hair checking and later, surface scaling. This can be prevented by protecting the surfaces with an adequate curing medium and thus preventing evaporation.

Water Loss in Subgrade

A concrete pavement slab loses water in two ways; by evaporation, and by leakage into the subgrade. Where the subgrade is porous, like sand or loom, the latter loss is accelerated by absorption.

When the slab is sealed, immediately after finishing, by an impervious membrane, this action is materially retarded. Sealing the surface creates a semi-vacuum in the slab which stops this subgrade absorption. A cure that forms a tight film is the only method that will eliminate this water loss.

Crack Control

When concrete is not protected, surface cracks develop, due to too rapid drying, which causes unequal shrinkage between the surface and interior of the slab. This condition can be stopped by early curing which tends to produce more uniformity in the structure until the concrete has had an opportunity to develop sufficient strength to overcome such strains.

Water Curing

Water Curing is probably as efficient a method as can be used, but it is impractical for field usage. Large quantities of water are often difficult, and sometimes impossible, to obtain. The cost of continuous spraying is generally prohibitive, due to the necessity of constructing pipe lines and maintaining an adequate water supply.

Ponding

Ponding has been extensively used. This method is satisfactory only to the extent that the earth dams are not damaged, with a consequent draining of the water seal, and exposure of the surface. Cleaning the mud and dust from the surface at the end of the curing period is expensive, and the surface is generally left in a dirty and discolored condition.

Ponding

Calcium Chloride Curing

Calcium Chloride is used for curing both as a surface application and as an admixture.

Where surface application is used the concrete slab is protected for the first twenty-four hours with wetted burlap. After the burlap is removed, flake Calcium Chloride is spread over the pavement at the rate of 2 to 3 pounds per square yard. This material cannot be applied during wet weather, and if a rainfall occurs within two or three hours after application, an additional application must be made.

When the admixture method is used, the material is added, in solution with the mixing water, at the rate of approximately two pounds per sack of cement. The surface of the slab must be protected with wetted burlap to prevent surface drying and consequent cracking or hair checking.

Sodium Silicate Curing

Sodium Silicate curing is somewhat similar to the surface application of Calcium Chloride. The pavement is first protected for twenty-four hours with wetted burlap. After the burlap is removed a solution of Sodium Silicate (water-glass) is brushed over the surface. If rain occurs before this has hardened (a period of some hours) the Sodium Silicate will wash off and must be replaced.

Water Retentive Materials

The application of *wet burlap* is satisfactory, providing the burlap is kept in a saturated condition. If this is neglected, the covering material acts as a blotter, and absorbs water from the surface, rather than protecting it.

A method extensively used is the application of saturated burlap for twenty-four (24) hours, and following with a layer of wet hay earth for the balance of the curing period. This method is satisfactory only to the extent that the covering materials are kept constantly saturated. This, as in some of the other methods using water, brings in the human equation, and, obviously, is an expensive cure, since it involves the cost of burlap, hay, a large amount of water, and labor to place, keep the hay saturated and remove it before the roadway is opened to traffic.

Bituminous Curing

During the past few years the use of dirt and water, hay and water, and ponding or water spray has been largely superceded by bituminous material sprayed on the fresh concrete immediately after it has been deposited and finished. A properly blended bituminous compound forms an impervious film over the surface of the concrete, sealing the mixing water and assuring complete hydration. No further attention is required, other than protecting the surface from traffic (in the case of pavements) by suitable barricades.

Applying Hunt Process Directly Behind Finishing Machine

HUNT PROCESS is a bituminous compound, designed and processed especially for curing concrete. When sprayed on the surface of the slab it forms a tough, impervious film. It does not peel or chip off. For the first few days it is jet black in color, and later, under traffic, becomes a dull gray color, forming an ideal kill-glare surface.

The Simple and Efficient Method

Bituminous curing eliminates the "human element." When HUNT PROCESS is sprayed on the concrete, a curing film is immediately produced, requiring no further attention.

Description of Tests at Columbia University Laboratory

Testing 6" x 8" Cylinders

Series No. 1—A study of the effect of curing conditions upon the compressive strength of concrete specimens, stored in order to prevent evaporation of mixing water from the sides and bottom; with the top surfaces exposed to air at 70° F., while covered with wet burlap, or coated with bituminous compound.

Series No. 2—A study of the effect of curing conditions upon the compressive strength of concrete specimens, all surfaces of which were exposed to air twenty-four (24) hours after molding.

(a) Untreated, and stored in air at 70° F.
(b) Untreated, and stored in moist room at 70° F.
(c) Coated with bituminous compound, and stored in air at 70° F.

Series No. 3—A study of the effect of various bituminous coatings upon the normal evaporation of mixing water. Specimens coated with:

(a) Native asphalt compound.
(b) Asphalt Emulsion.
(c) Petroleum asphalt cut-back.

All specimens were stored in air at 70° F., and weighed daily on a torsion balance to determine difference in weight, or moisture loss.

Series No. 4—A study of the variation of the compressive strength in the various strata from top to bottom of a mass of concrete. The specimens were stored in order to prevent evaporation from the sides or bottom; while the top surfaces were untreated, or coated, with bituminous curing compound and exposed to air. This test indicated the progressive loss in strength from the surface to the interior of the mass, due to evaporation through the surface.

Series No. 5—A study of the variations of abrasion (resistance to wear) in the various strata of concrete specimens, cured and stored, as described in Series No. 4.

Series No. 6—A study of the effect of sunlight upon the drying properties of various bituminous cures, and visible appearance when applied to concrete surfaces.

Series No. 7—Examination of the continuity of curing coatings produced by various bituminous cures.

Preparation of Specimens, Tests, and Test Data

Test Series No. 1—In a concrete highway slab the evaporation of mixing water from the sides and bottom is relatively small, due to its embedment in damp soil. The greater part of the evaporation consequently occurs at the top surface, which is exposed to air under varying temperature and humidity conditions.

Specimens, Surface Treated and Stored in Damp Sand

To simulate such exposure, the test specimens were made in the form of cylinders, six inches (6") in diameter by eight inches (8") high. (Representing average highway slab thickness.) These were cast and stored in twenty (20) gauge sheet iron molds, in order to prevent evaporation of mixing water, except by evaporation through the top surface. All specimens were stored under the same temperature and humidity conditions until tested for compressive strength at the end of seven (7), fourteen (14), twenty-one (21), and twenty-eight (28) days.

To insure uniformity in the specimens, each cylinder was proportioned, mixed and cast separately, the quantities of materials being weighed for each specimen.

The mix consisted of volumetric proportions of dry-loose materials of one (1) part Portland cement; one and three-quarters (1¾) parts Cow-bay sand; and three and one-half (3½) parts of graded, broken trap rock. The water-cement ratio was 5.25 gallons per sack of cement. The slump was one and one-half (1½") inches. All specimens were mixed, placed, and rodded in accordance with the methods specified by the American Society for Testing Materials.

Seventy-two (72) specimens were made; thirty-six (36) of which were sprayed with bituminous compound. Thirty-six (36) were covered with wet burlap for twenty-four (24) hours, and then coated with bituminous compound. In each half of the series, twelve (12) specimens were coated with a native asphalt compound; twelve (12) with an asphaltic emulsion, and twelve (12) with a petroleum asphalt cut-back. Specimens were tested at seven (7), fourteen (14), twenty-one (21), and twenty-eight (28) days.

The results of the test, which was made to show the effect of the twenty-four (24) hour burlap cure, as compared to a bituminous cure applied immediately, were as follows:

TABLE No. 1

Series No. 1—Compressive Tests in Pounds per Square Inch

Seven Days

Top surface treated with bituminous cure immediately	Average	Overall average	*Top surface treated with wet burlap for twenty-four hours (24), and followed by bituminous cure*	Average	Overall average
3670, 3525, 3640	= 3612		3605, 3430, 3875	= 3637	
3310, 3360, 3655	= 3442	3599	3150, 3470, 3320	= 3313	3560
3670, 3740, 3790	= 3733		3520, 3875, 3795	= 3730	

Fourteen Days

Top surface treated with bituminous cure immediately	Average	Overall average	*Top surface treated with wet burlap for twenty-four hours (24), and followed by bituminous cure*	Average	Overall average
4143, 4287, 3650	= 4026		4090, 3315, 3700	= 3702	
3880, 3800, 3830	= 3837	3995	3830, 3720, 4070	= 3873	3887
5050, 3765, 3550	= 4122		4280, 3950, 4030	= 4087	

Twenty-one Days

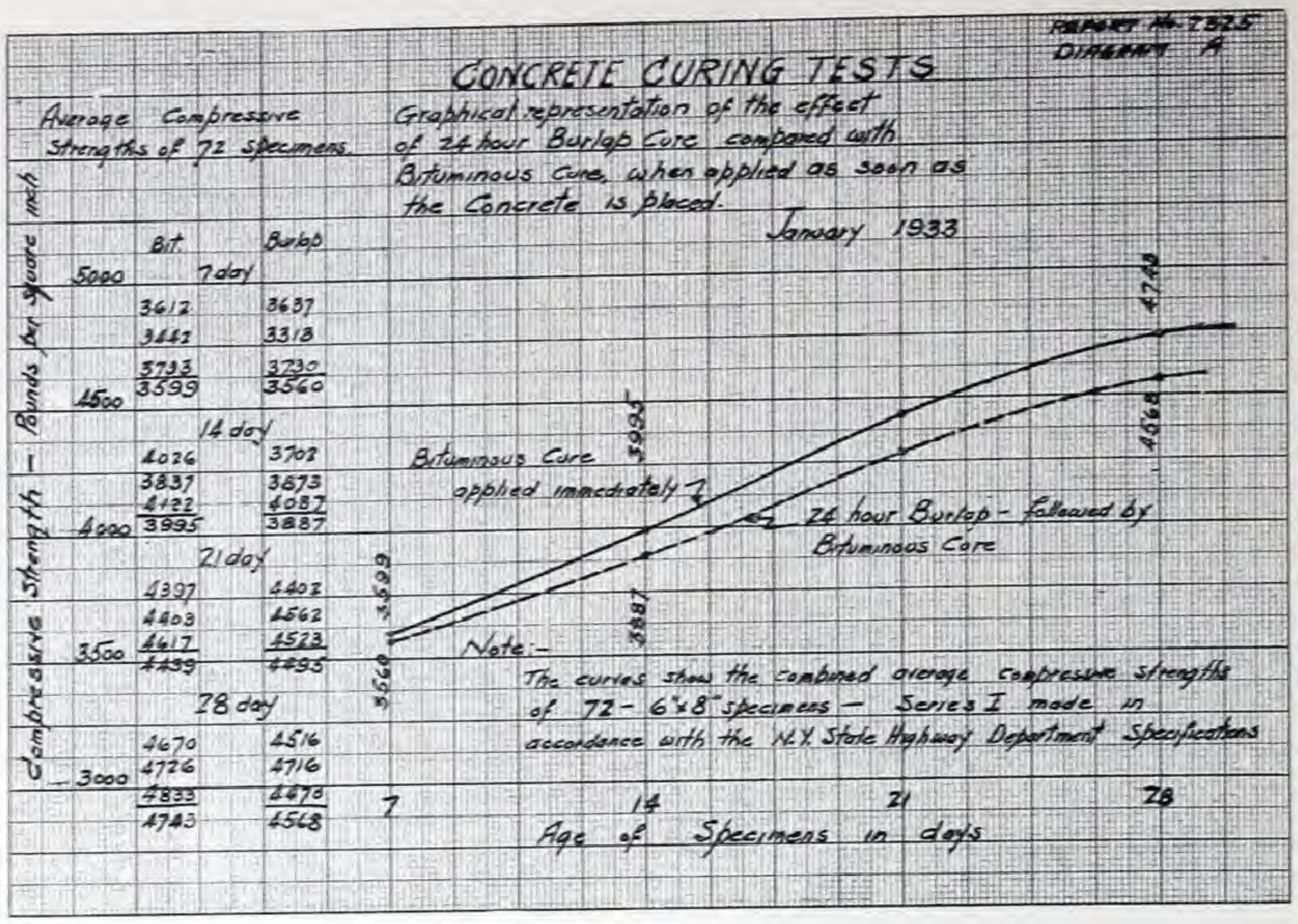
Top surface treated with bituminous cure immediately	Average	Overall average	*Top surface treated with wet burlap for twenty-four hours (24), and followed by bituminous cure*	Average	Overall average
4210, 4370, 4610	= 4397		4130, 4430, 4645	= 4402	
4025, 5020, 4165	= 4403	4472	4575, 4560, 4550	= 4562	4495
4520, 5065, 4265	= 4617		4650, 4560, 4360	= 4523	

Twenty-eight Days

Top surface treated with bituminous cure immediately	Average	Overall average	*Top surface treated with wet burlap for twenty-four hours (24), and followed by bituminous cure*	Average	Overall average
5040, 4430, 4540	= 4670		4650, 4530, 4370	= 4516	
5090, 4400, 4690	= 4726	4743	4880, 4630, 4640	= 4716	4568
4750, 5160, 4600	= 4833		4060, 4450, 4910	= 4473	

The broken stone aggregate, having maximum size of one and seven-eighths inches (1⅞″), was used in the concrete mixture for this test. Some difficulty was experienced in rodding the mixture, and the fractures of the specimens indicated a tendency of the larger aggregate to "bunch," which was undoubtedly due to the rodding.

The specimens were broken (dry) in the conditions resulting from the curing, and probably had different moisture contents. A comparison of the results, therefore, involves the extent to which the retained moisture content has affected the apparent strength. The irregularities in the various specimens throughout the series may be attributed to the harshness of the mix, and to the fact that the *specimens were tested without soaking.*



Series No. 2—In this series of tests, all surfaces of the specimens, *i.e.*, the sides and bottom, as well as the top, were subjected to the same treatment, and curing conditions, rather than the exposure of the top surface only. The specimens were in the form of six inch (6") diameter cylinders, eight inches (8") high—(representing average highway slab thickness)—molded in twenty gauge (20) sheet metal forms. The mix used corresponded to the volumetric proportions of one (1) part Portland cement; one and three-quarters (1¾) parts Cow-bay sand; and three and one-half (3½) parts of graded gravel. The water-cement ratio was 5.25 gallons per sack of cement. The slump two inches (2"). Each specimen was made from a separate batch, the materials being proportioned by weight.

Fifteen (15) cylinders were prepared. Ten (10) of these were given no surface treatment; five (5) were stored in the moist room, and five (5) were stored in air at 70° F. until tested for compression at twenty-eight (28) days. The remaining five (5) specimens were coated with bituminous compound, applied to the top surface immediately after the concrete was deposited, and to the sides and bottom at the end of twenty-four (24) hours, when the sheet metal forms were stripped. These specimens were stored in air at 70° F. until tested at twenty-eight (28) days.

To eliminate the effect of moisture content upon the relative strength, each of the specimens in the series was stored in water for forty-eight (48) hours, and tested in a saturated condition. To permit uniform absorption, the surfaces of the coated specimens were cleaned with a rasp, removing the bituminous film before immersion in water.

The results of this test are as follows: (In computing relative strengths, moist room curing was assumed as 100%.)

TABLE No. 2

Series No. 2—Compressive Tests

Specimens 6" x 8" Cylinders—Gravel Aggregate—Age 28 Days

Mark	*Surface Treatment*	*Storage Conditions*	*Compressive Strength Lbs./Sq. In.*	*Average*	*Relative Strength*
A-1	None	Air—70° F.	3947		
2	"	"	4127		
3	"	"	3954		
4	"	"	4174		
5	"	"	3948	4030	84.2%
M-1	None	Moist. Rm.—70° F.	4946		
2	"	"	3987*		
3	"	"	4561		
4	"	"	4983		
5	"	"	4635	4781	100.0%
C-1	All surfaces	Air—70° F.	5041		
2	coated with	"	4788		
3	bituminous	"	4767		
4	compound	"	4602		
5		"	4837	4807	100.5%

(* Not included in average.)

TABLE No. 5

Percent of Relative Loss of Mixing Water

Time of Exposure	*No Coating*	*Asphalt Emulsion*	*Petroleum Asphalt Cut-Back*	*Native Asphalt Compound*
1 Day	100%	43.0%	43.0%	20.0%
3 Days	100%	59.5%	51.7%	28.8%
7 Days	100%	69.8%	60.5%	38.4%
28 Days	100%	80.0%	69.6%	54.3%
94 Days	100%	89.2%	80.9%	70.4%

NOTE.—The time shown is after stripping forms—For Total Age, add Eighteen (18) Hours.

Series No. 3—This test was to determine the effectiveness of various bituminous coatings in preventing evaporation of mixing water from a concrete mass.

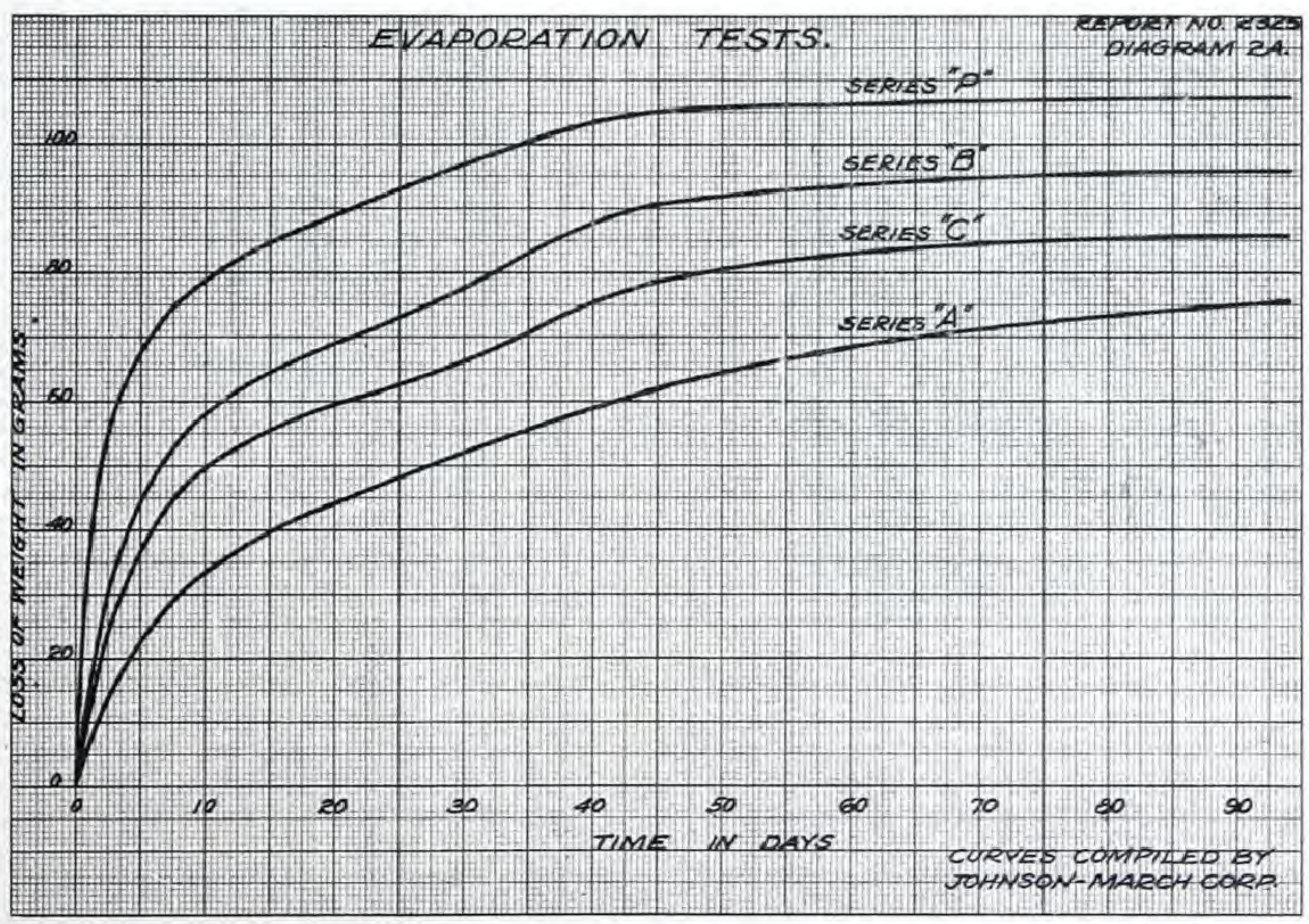
The specimens were prepared in the form of cylindrical discs, three inches (3″) high by six inches (6″) diameter, composed of concrete mixed in the volumetric proportion of 1 - 1¾ - 3½, with broken stone coarse aggregate. The water-cement ratio was 5.25 gallons per sack of cement. The slump was one and one-half (1½″) inches. The reduced size of the specimens made it possible to weigh them on a torsion balance to grams.

A total of twelve (12) specimens were prepared and left in the molds for twenty-four (24) hours. Three (3) specimens received no further surface treatment. Three (3) each were treated with a native asphalt compound, an asphaltic emulsion, and a petroleum asphalt cut-back, respectively. The coatings were applied to the top surface immediately after molding, and to the sides and bottom after stripping the forms twenty-four (24) hours later. All specimens were stored in air.

Two (2) specimens in each group were exposed intermittently to the light of an S-1 sun-lamp. The duration of light exposure was seven (7) hours per day, and continued for a total exposure of one hundred and twenty-one (121) hours. There appeared to be no consistent difference between the loss of moisture of the specimens exposed to sun-lamp and those stored in air at 70° F.

Each specimen in this series was weighed daily for forty (40) days, and finally at ninety-four (94) days.

Table No. 5 gives the percentage relationship, based on corrected values of Table No. 4 to include estimated loss by evaporation during the first eighteen (18) hours while in molds, of the various groups of specimens, based on the loss of the untreated specimens, assumed as one hundred (100%) percent.



P = Air dried with no surface treatment.

B = Surface treated with asphalt emulsions

C = Surface treated with asphalt cutback.

A = Surface treated with asphalt Hunt Process.

Note: The rapid evaporation during the first few days and the necessity for application of the curing film as soon as possible after the concrete has been deposited and finished is indicated very clearly by the above graph.

Investigation of Variations in Strength Due to Evaporation at Various Depths below the Surface of an 8-Inch Concrete Slab

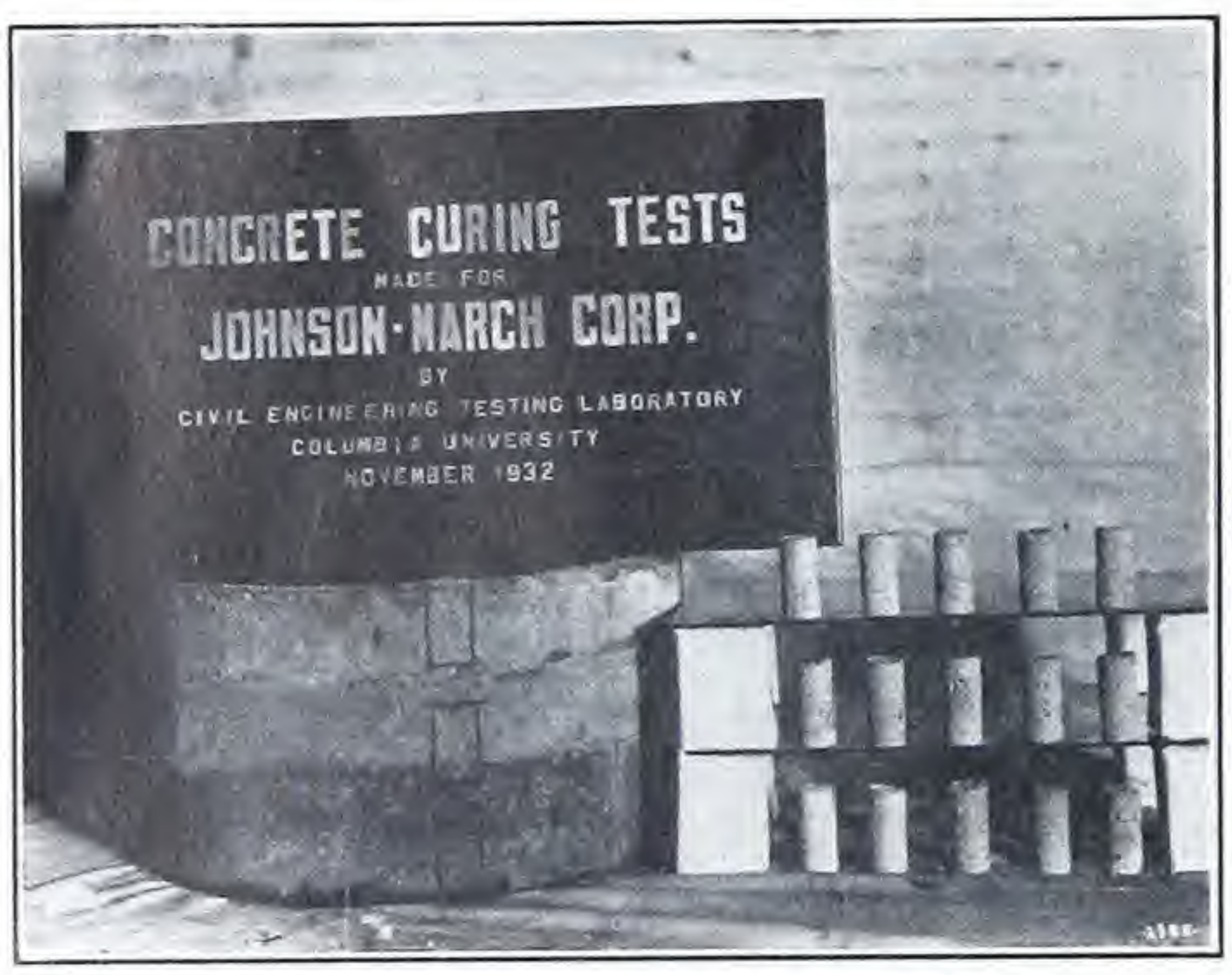
Series No. 4—Variations of Strength in Various Strata.

This series of tests was made to determine the variation in compressive strength throughout the depth of a mass of concrete, when the top surfaces were either untreated, or coated with bituminous compounds, and stored in air at 70° F. It was decided to eliminate the coarse aggregate and to use mortar in order to produce a more uniform mixture, and thereby reduce the effect of large particles in the one (1″) inch cores, which were subsequently drilled from the various strata.

The specimens were prepared in the forms of cylinders eighteen inches (18″) diameter by eight inches (8″) high, composed of mortar mixed in the volumetric proportions of one (1) part cement to three (3) parts Cow-bay sand. The water-cement ratio was 6.8 gallons per sack of cement. The sand used was natural grading with particles above one-quarter (¼″) inch screened out.

Four (4) such cylinders were made in sheet metal molds. The top surface of one of these cylinders received no further treatment, while the top surfaces of the other three (3) were coated with a native asphalt compound, an asphaltic emulsion, and a petroleum asphalt cut-back, respectively.

These four cylinders were stored in damp sand, and in metal forms, with the top surfaces exposed to air at 70° F.



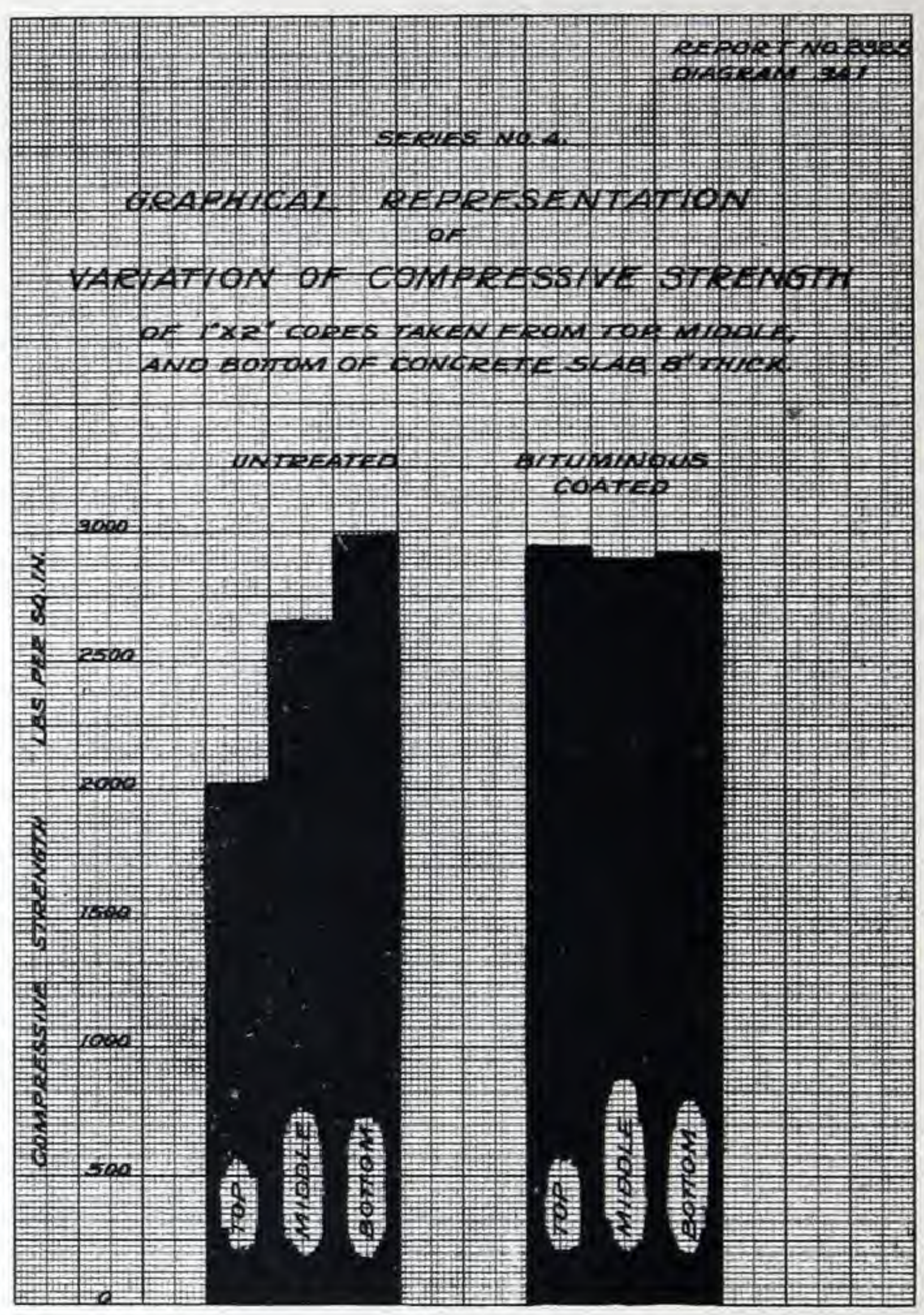
Large Cylinders and Cores Cut Therefrom

At the end of twenty-eight (28) days curing, the eighteen inch (18″) by eight inch (8″) cylinders were separated into the three (3) layers, or strata, and one inch (1″) diameter cores were cut with a diamond drill from each layer, normal to the surface, in order to provide specimens representing the material of the upper, middle and lower portions of the concrete slab. These cores were cut to exact length of two inches (2″), and faced on a lap.

All cores, prepared as described, were saturated with water, and tested for compressive strength. The results are shown in Table No. 6.

The results of this test indicate that the bituminous surface coating was effective in producing a more uniform curing condition as compared with the curing resulting from exposure of the top surface without treatment or precaution against evaporation. It also indicates a greater average strength.

The variation in strength of cores two inches (2″) long, taken from the top and bottom of an eight inch (8″) slab, without surface treatment, was about nine hundred (900) pounds per square inch. The strength variation of the various strata of the coated blocks was less than one hundred (100) pounds per square inch.



Showing Progressive Effect of Free Evaporation from Top to Bottom of Slab

The variations of strength of the untreated specimen indicate a still further decrease of strength of the material adjacent to the surface. The cores drilled from the top strata probably represent the strength of the material about one (1″) inch from the surface.

Irregularities in the relationship between cores—(while small)—are probably due to the difficulties incident to preparing a uniform mass for each slab. Some differences may exist due to preparing the four (4) cylinders from four (4) different batches of material, but the strengths of the cores were probably more seriously affected by the sand graduation used.

In drilling the cores, it was observed that occasionally large particles (one-quarter of an inch (¼″) in diameter) were included in the cores, and that the larger sand grains tended to dislodge from the surfaces during drilling, leaving voids. These various variables probably account for the variations in the individual values shown.

TABLE No. 6

Series No. 4—Compression Tests on Cores

From Top, Middle and Bottom of 8" Concrete Slab
Specimens 1" x 2"—Age 28 Days

UNTREATED TOP SURFACE

	Top 2"	*Middle 2"*	*Bottom 2"*
	2115	2650	3000
	2000	2795	2890
	2170	2665	3120
	2250	2545	2865
	1635	2650	3040
Avg.	2034	2661	2983

Average Strength = 2559 Lbs.

TOP SURFACE TREATED WITH BITUMINOUS COMPOUNDS

	Top	*Middle*	*Bottom*
	2490	2675	2970
	2810	3000	2970
	2545	2905	2315
	2650	2770	2785
	2715	2810	3160
	2610	....	....
	3185	....	....
	3105	....	....
	2650	....	....
	2890	2915	2865
	2905	2875	2730
	2930	2825	3010
	3010	2905	3120
	3050	2970	3385
	2785	3010	3130
	3240	2705	2920
	2810	3080	2705
	3455	3065	2985
	3400	2755	2770
Avg.	2907	2884	2921

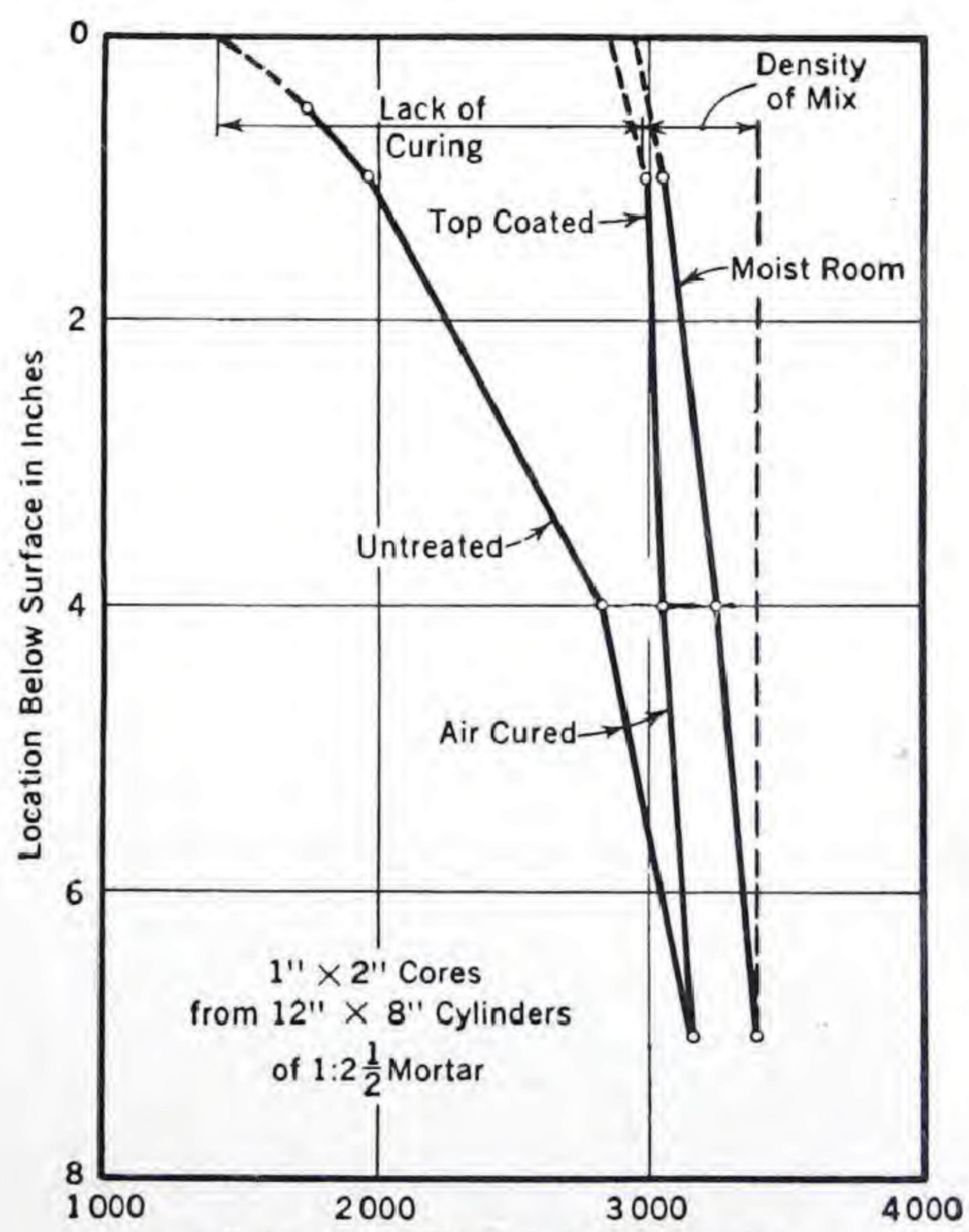
Average Strength = 2904 Lbs.
Increase in strength of top section due to curing = 873 lbs. = 43.0%
Average increase of strength due to curing = 345 lbs. = 13.5%

Series No. 4A—Due to the variables noted in Series No. 4, a similar series of tests was made, for which three (3) cylinders were cast from a single batch of material.

The batch was mixed in the volumetric proportions of one (1) part Portland cement, to two and one-half (2½) parts sand, with water at the rate of 6.6 gallons per sack of cement. The sand was screened to include particles retained on the 100 and passing the 14 mesh sieves. Each cylinder was rodded similarly during molding in sheet iron forms.

One (1) cylinder received no surface treatment, and was stored on a bed of damp sand, with the top exposed to air at 70° F. A second cylinder received no surface treatment, but was stored in a moist room at 70° F. The third was coated with bituminous compound on the top surface immediately after molding, and stored on a bed of damp sand, with top surface exposed to air at 70° F.

At the age of twenty-eight (28) days, these cylinders were cut into three (3) layers, or strata, with a diamond edge saw, and cores were drilled from each layer, representing the top, middle and bottom of the eight (8") inch slab. The cores were saturated with water and tested for compression, with the results shown in Table No. 7 on the following page.



Average Compressive Strengths of Cores from the Top, Middle, and Bottom of Mortar Cylinders
Detrimental Effect of Incomplete Curing on Top Layers and Beneficial Effect of Increased Density on Bottom Layers

TABLE No. 7

Series No. 4-A—Compression Tests on Cores

Specimens 1" x 2" Cores—Age 28 Days

AIR CURING—SURFACE TREATED WITH BITUMINOUS COMPOUND

	Top 2"	*Middle 2"*	*Bottom 2"*
	2910	2740	3140
	3100	3025	3110
	3270	3170	3400
	2740	3370	3315
	3255	2995	3185
Avg.	3055	3060	3230

Average Strength = 3115 Lbs.

MOIST ROOM CURING—NO SURFACE TREATMENT

	Top 2"	*Middle 2"*	*Bottom 2"*
	2910	2840	3255
	3070	3010	3200
	3230	2870	3255
	3200	3170	3070
	3230	2795	3200
Avg.	3128	2937	3196

Average Strength = 3087 Lbs.

AIR CURING—NO SURFACE TREATMENT

	Top 2"	*Middle 2"*	*Bottom 2"*
	1730	2840	2940
	1845	2635	3085
	2090	2695	3040
	1990	2825	3070
	2045	2855	2855
Avg.	1940	2770	2998

Average Strength = 2569 Lbs.

Loss in strength	=	**Top to Middle**	=	**830 lbs.**	=	**30.0%**
Loss in strength	=	**Middle to Bottom**	=	**228 lbs.**	=	**7.6%**
Loss in strength	=	**Top to Bottom**	=	**1058 lbs.**	=	**35.0%**

The 1" x 2" cores drilled from the top strata of these specimens probably represents the strength of the material one (1") inch from the surface. In order to determine the strength as near the surface of the slab as possible, supplementary compressive tests were made on cores taken from the upper inch, and also upon cores two (2") inches long, drilled parallel to the upper surface in order to include material in the upper inch adjacent to the exposed surface, or in the sections upon which the effect of evaporation of mixing water is the greatest.

The results of these tests are as follows:

TABLE No. 8

Compression Tests on 1" x 1" Cores

Specimens 1" x 1" Taken Normal and Adjacent to Top Surfaces

Type of Curing	*Compressive Strength Lbs. per Sq. In.*	*Average*
Air Cured No Surface Treatment	1770	
	1770	
	1525	
	1945	
	1875	1777
Moist Room Curing No Surface Treatment	3025	
	3085	
	2795	
	3085	
	3370	3072
Air Cured Surface Coated with Bituminous Compound	3140	
	3185	
	2995	
	3170	
	2970	3092

Assuming that the moist room curing is one hundred (100%) percent efficient, the relative values are:

Air Curing	=	**1777 lbs.**	=	**58.0%**
Moist Room Cure	=	**3072 lbs.**	=	**100.0%**
Bituminous Cure	=	**3092 lbs.**	=	**100.6%**

TABLE No. 9

Compression Test on 1" x 2" Cores Drilled Parallel and Adjacent to Top Surface

Type of Curing	*Compressive Strength Lbs. per Sq. In.*	*Average*
Air Curing No Surface Treatment	1815	
	1745	
	1760	1773
Moist Room Curing No Surface Treatment	2880	
	3140	
	3255	3092
Air Cured, Surface Coated with Bituminous Compound	3445	
	3600	
	3330	3458

The moist room cured and the bituminous cured slabs compare very closely in strength, while the air cured (no treatment) falls considerably below either in strength.

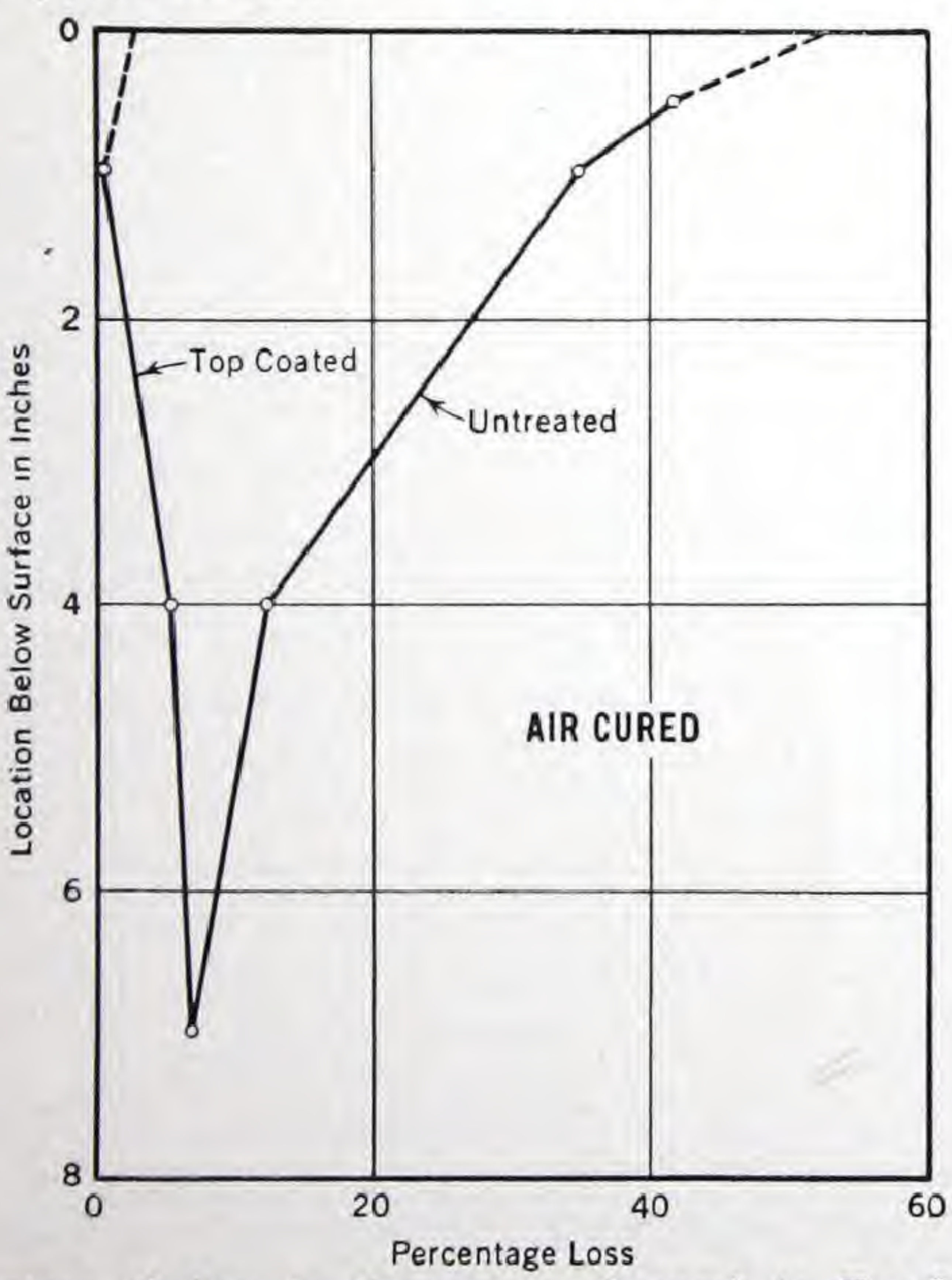
Considering the variations of strength in the various specimens, and assuming the strength shown for the bottom of each slab as one hundred (100%) percent, the following relations are obtained:

TABLE No. 10

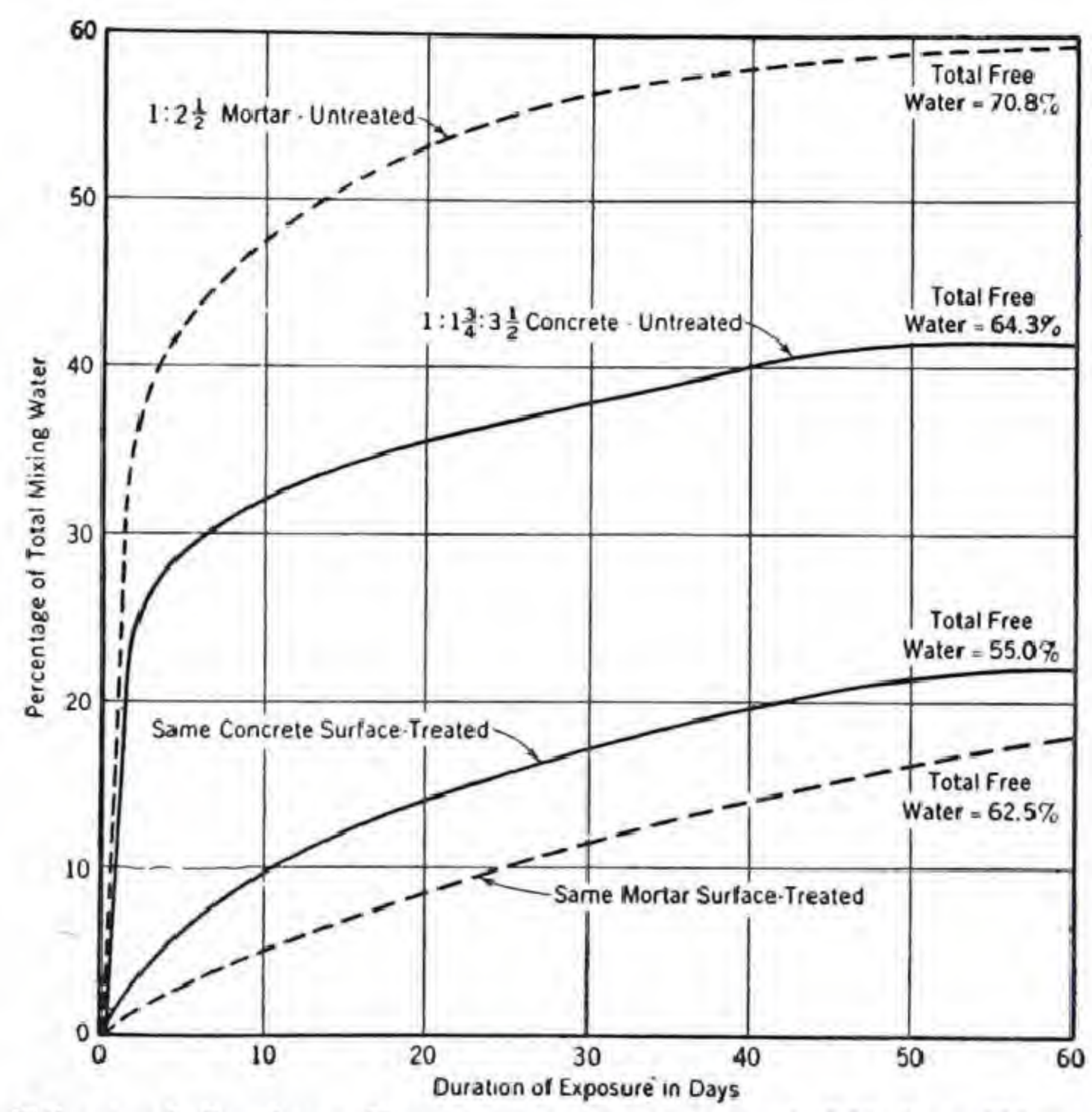
	Air Cured No surface treatment	*Moist Room Cured No surface treatment*	*Air Cured Bituminous Surface treatment*
Bottom 2"	100.0%	100.0%	100.0%
Middle 2"	92.5%	91.9%	94.7%
Top 2"	64.7%	97.9%	94.5%
*Top 1"	59.1%	96.7%	107.5%

* Based on 1" x 2" Cores taken parallel and adjacent to surface.

It will be noted that the strengths of the moist room cured and bituminous cured specimens are nearly uniform. The untreated specimens, exposed to air without precautions against evaporation of mixing water, show a marked progressive decrease in strength toward the exposed surface.



Percentage of Loss in Compressive Strength in Top-Coated and Untreated Cylinders
Top Layers of Untreated Cylinders Lost About 50 Per Cent in Strength as Compared with Cured Specimens



Effect of Surface Treatment on Loss of Mixing Water by Evaporation
Concrete and Mortar Specimens Exposed to Air at 71 F and 69 Per Cent Relative Humidity

The losses by evaporation are expressed in terms of percentage of total mixing water used in each set of specimens. These curves indicate clearly that, without protection against evaporation, a very large part of the total water ultimately evaporated is lost within the first few days of exposure. About 40 per cent of the total water lost during 60 days of exposure evaporated during the first day, and about 65 per cent had disappeared at the end of three days.

A Study of the Resistance to Abrasion or the Increase in Wearing Qualities of Concrete Due to Adequate Curing

Series No. 5—Abrasion or Wear Tests.

As a means of determining the effect of surface treatment, or curing, upon the other physical properties of Portland Cement concrete, tests were made of the relative resistance to abrasion, or wear.

One (1") inch diameter cores, drilled from the three (3) layers (or strata) of the specimens used for tests described in Series No. 4, were subjected to the "Hardness" test, as applied to rock materials on a Dorry machine.

The machine was operated for five hundred (500) revolutions on each sample, after which the loss of weight was determined, and used as an index of relative resistance to wear. Samples from the top, middle and bottom of each specimen were tested.

This test subjects the samples to abrasion, or wear, and a clipping action, which tends to remove particles from the mass. All specimens were dried before testing.

The following table gives the results of this test:

TABLE No. 11

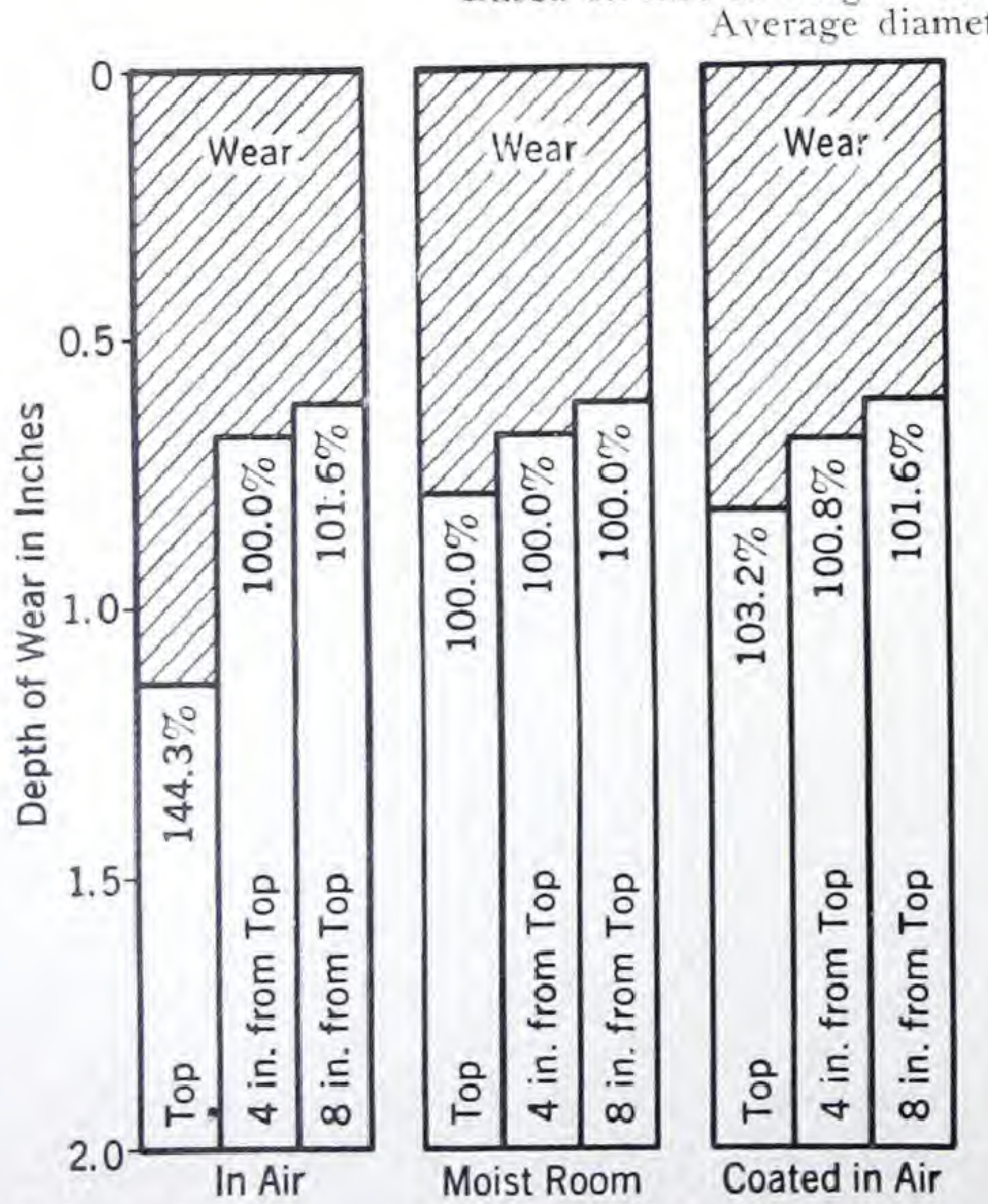
Abrasion Tests on Cores

Specimens 1" Diameter Cores—Tested Dry—Age 28 Days

Material—Cores from top, middle and bottom of Mortar Blocks 8" thick.
Mark M = No surface treatment, stored in moist room.
Mark A = No surface treatment, stored in air.
Mark C = Top surface coated with compound "A"—stored in air.

	Loss in Weight, Grams			*Decrease in Length of Core in Inches**		
Mark	*Top*	*Middle*	*Bottom*	*Top*	*Middle*	*Bottom*
M.	17.5	16.0	13.0	0.78	0.72	0.58
	15.5	14.0	12.5	0.69	0.63	0.56
	17.0	14.5	11.5	0.76	0.65	0.51
			10.5			0.47
Average	16.7	14.8	11.9	0.75	0.66	0.53
A.	28.0	14.5	13.0	1.25	0.65	0.58
	26.5	16.0	11.5	1.19	0.72	0.51
	28.0	14.0	13.5	1.25	0.63	0.60
		12.0	15.0		0.54	0.67
Average	27.5	14.1	13.3	1.23	0.63	0.60
C.	17.5	17.0	13.0	0.78	0.76	0.58
	18.0	14.0	12.5	0.81	0.63	0.60
	18.0	14.5	12.5	0.81	0.65	0.60
			15.0			0.67
Average.	17.8	15.2	13.3	0.80	0.68	0.60

Based on loss of weights shown, unit weight = 123 lbs. cu. ft.—and
Average diameter of Core = .94 Inches.



Relative Resistance to Wear of 1" Diameter Cores on Dorry "Hardness" Machine

The results of this test indicate a progressive decrease in wear resistance as the top surface is approached. The resistance to wear does not appear to be greatly different at the middle and bottom of the three (3) specimens, and agrees within the limits of experimental variations to be expected in this type of test. The resistance to wear of the top surface material shows marked differences between the untreated (or unprotected) surface, and those of either moist cured or bituminous cured. The untreated air cured surface shows approximately sixty percent (60%) greater wear than the surface material of the moist cured or bituminous coated specimens.

The graphic representations at the left (based on moist room curing being 100% efficient) shows that the middle and bottom sections are practically the same in all three cases and that the moist room and bituminous cured surfaces almost on a par, but the upper strata of the specimen cured in air has lost over 40%.

Series No. 6—Drying Properties and Visible Appearance of Various Bituminous Coatings.

Observations were made on coatings produced by a native asphalt compound, an asphaltic emulsion, and a petroleum asphalt cut-back, when applied to concrete surfaces.

The native asphalt compound was dry to touch after twenty-four (24) hours.

The petroleum asphalt cut-back appeared dry after about three (3) days.

The asphaltic emulsion remained somewhat "tacky" at ninety-four (94) days.

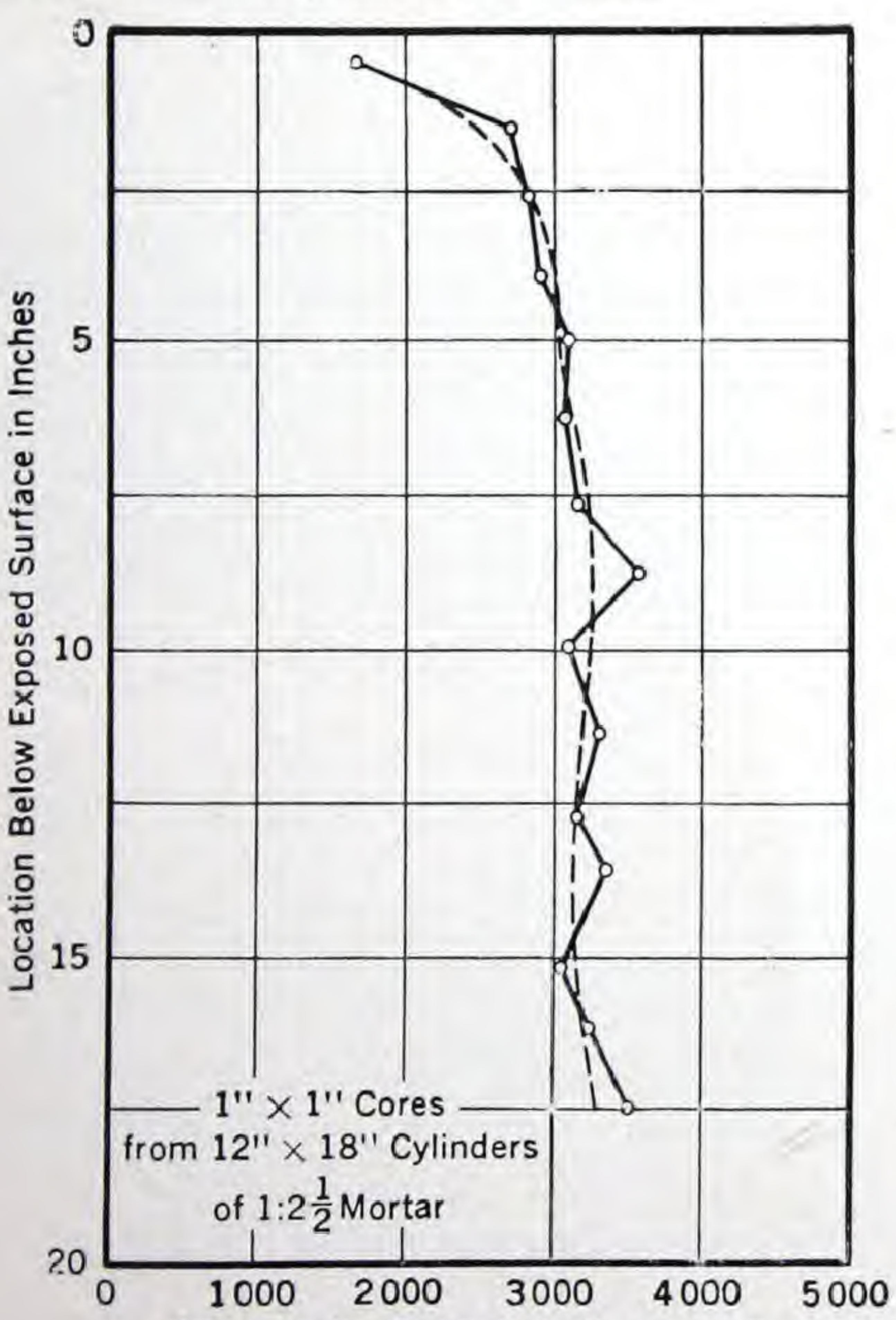
The same materials when applied to glass plates, showed similar drying effects.

Exposure to the light of a sunlamp did not seem to affect the rate of drying of any of the compounds, nor was any cracking, or checking, produced.

Series No. 7—In order to determine the continuity of the film produced by various asphaltic compounds, glass plates were coated on one side with a native asphalt compound, an asphaltic emulsion, and a petroleum asphalt cut-back.

To obtain an evenly coated surface, the compounds were poured and spread on the glass plates, and then allowed to drain off, by holding the plates vertical.

After drying, inspection was made by holding the plates to the light. Such observation showed the asphaltic emulsion to have numerous pin holes distributed throughout. The petroleum asphalt cut-back showed similar holes, but much smaller in size. The native asphalt compound showed a few fine pin holes, but in general this material appeared to have considerably better continuity than the others.



Variations of Compressive Strength, Due to Lack of Curing to a Depth of 18". This Demonstrates the Rapid Decrease of Strength as the Surface Is Approached

Evaporation Limit

In order to determine the approximate depth at which evaporation ceases to reduce the strength of a mass of concrete, a cylinder 18" deep and 12" diameter was cast. A steel mold was used with the bottom sealed. This specimen was stored at 70% for 28 days with the top surface unprotected.

The cylinder was sawed into inch layers, as heretofore described and one inch diameter cylinders sawed therefrom. The results of this investigation are shown on the accompanying diagram. It is quite apparent that the detrimental effect of evaporation is felt to a depth of at least 8 inches. The greatest loss, of course, is near the surface.

Summary and Conclusion

The data furnished by the hereinbefore described tests indicates:

(1) That bituminous curing applied as soon as the concrete has been deposited and finished, is more effective than when applied after twenty-four (24) hours burlap curing.

(2) That the application of bituminous coating in general results in considerably higher strength concrete than when the same concrete is unprotected from evaporation during the curing period.

(3) That bituminous curing is equal in effectiveness to moist room curing. That the unprotected (or uncured) concrete shows an average loss in strength of about sixteen (16%) percent.

(4) That evaporation of the mixing water is retarded by the application of bituminous surface coating, and that the native asphalt compound appears to be the most effective of the three materials tested.

(5) That the compressive strength of a mass of concrete varies throughout the depth of the slab. The loss of strength is dependent on the amount of evaporation of the mixing water, and the resultant lack of curing.

(6) That surface coating with a bituminous compound and moist room curing each produce an equally uniform strength throughout slab, whereas the strength of the material adjacent to the surface of an untreated and unprotected slab decreases about forty (40%) percent.

(7) That resistance to abrasion is dependent on proper curing, as indicated by the small differences throughout the slab in the moist cured and bituminous coated specimens, while the untreated and unprotected specimens showed a large variation, or about one hundred (100%) percent greater at the top than at the bottom of the slab, *i.e.*, the resistance to wear of uncured concrete is approximately one-half.

(8) That the native asphalt compound drys more quickly and forms a more impervious film than either the asphaltic emulsion, or the petroleum asphalt cut-back.

The native asphalt compound used as a cure in the series of tests was "HUNT PROCESS."

Why Hunt Process Is the Ideal Method of Concrete Curing

What Hunt Process Is

"Hunt Process" is a compound composed chiefly of Bermudez Asphalt, and Gilsonite, blended at a high temperature, thinned to working consistency with a petroleum solvent. It has a marked affinity for unset concrete, adhering to the surface and forming a water-tight and air-tight seal. It dries rapidly and forms a film of uniform texture, free from pin holes.

Hunt Process, One Man, Spray Machine

A Protective Film

While the concrete is still wet the application of "Hunt Process" forms a thin, water and air-proof sheet having great flexibility and toughness. With the hardening of the concrete, the "Hunt Process" also hardens and adheres firmly to the concrete, virtually becoming a part of the surface without penetrating into it.

Hunt Process Film on "Green" Concrete

Why Use "Hunt Process"

Eliminates use of earth and water and all other moisture retentive materials.

Prevents evaporation of the mixing water, and thus provides for a complete hydration of the cement. This eliminates hair checking and results in greater abrasive strength of the wearing surfaca.

Eliminates the fire hazard, the blowing away of cover material and the clogging of drains and catch basins which accompanies the curing by means of hay and straw.

The black color absorbs the sun's rays; raises the general temperature, and sustains the heat which is necessary for perfect hydration. "Hunt Process" results in a quicker hydration and a better crystallization of the mass to the *very surface*.

Does not require a preliminary covering of burlap, —in fact, requires no attention after application.

The concrete obtains the benefit of curing at the most critical period, as "Hunt Process" is applied immediately after finishing, while the concrete is still wet.

The film of "Hunt Process" becomes an integral part of the pavement. It will not peel or chip off. For the first few days it is jet black, and later, under traffic, becomes a dull gray color, creating an ideal "kill-glare" coat.

Produces a surface highly resistant to abrasion, for the surface is cured as completely as the concrete in the interior of the slab.

Typical Highway Job Cured with "Hunt Process"

Engineers and authorities on concrete recognize the fact that "the strength of concrete bears a well defined relation to the loss of mixing water during curing. The greater the loss of water, the greater the loss of strength"; also that "the efficiency of any curing method may be measured by its ability to prevent the loss of mixing water." Concrete cured by the "Hunt Process" *absolutely* retains the mixing water during the entire hardening period and insures maximum strength in the completed slab.

Labor Required

One intelligent laborer can handle the machine and apply the material.

Method of Application

"Hunt Process" is easily applied by the use of a single nozzle spray gun immediately after the concrete has been placed and finished.

The spraying unit consists of a pump driven by a gasoline motor in combination with a direct connected air compressor. This unit is mounted on a light two wheel trailer.

Hoover Dam—Diversion Tunnel-cured with "Hunt Process"

Concrete Pipe

The use of "Hunt Process" for the curing of concrete pipe is very advantageous. Both the inside and outside of the pipe should be coated to insure good curing.

Due to the thinness of the section of a reinforced concrete pipe, the steel is of necessity close to the surface and is subject to corrosion caused by water penetrating the concrete. The coating of bituminous material applied in the curing of concrete pipe by the "Hunt Process" resists the absorption of water by the concrete, and assists in preventing the corrosion of the reinforcing steel and the ultimate failure of the pipe.

Spraying Large Concrete Pipe Immediately After Stripping Forms

"Hunt Process" should not be compared with an ordinary asphalt cut-back, since it is designed, manufactured and sold for only one purpose—curing concrete. It is a specialist in its line.

Quantity Required

Because of the nature of the material and the method of application, a very thin film provides a waterproof coating. One gallon of "Hunt Process" will cover twenty (20) square yards of pavement if it is applied as directed and before the concrete is dry.

Simple to Apply. Easy to Inspect.
Where the pavement is black a film is formed that retains all the mixing water and assures complete hydration of the cement.

Curing Concrete Base for Bituminous Surfaces

The curing of concrete base for bituminous wearing surfaces deserves more attention than is usually given to it.

Not only does insufficiently cured concrete base suffer from lack of strength, but failure to retain sufficient moisture results in undue checking and cracking of the concrete. Such cracks not only affect the beam strength of the slab, but in time make their appearance in the surface of the bituminous surface.

"Hunt Process" is the best method of curing a concrete base, since the bituminous film acts as a binder between the concrete base and the bituminous wearing surface. When the hot bituminous pavement mixture is placed upon the base, the layer of "Hunt Process" is softened sufficiently to establish a bond between the two, cementing the top and base into a monolithic mass. This assists in preventing the "shoving" and "creeping" of the bituminous surface.

Cores from a New York City street. The two at ends cut from portion cured with Hunt Process, the two middle from non-cured portion. Note comparison of adhesion of asphalt top to concrete base.

Other Uses

In addition to pavements and concrete pipes, "Hunt Process" is the most efficient and economical bituminous cure for Reservoirs, Dams, Septic Tanks, Retaining Walls, Bridges, Piles and many other kinds of concrete structures.

SPECIFICATION

For Bituminous Curing of Cement Concrete Pavement

CURING PERIOD

The pavement shall be cured for the length of time required by the engineer. During this period the concrete shall be protected from traffic by adequate barricades. No material or equipment shall be placed on the curing concrete, nor shall the workmen be permitted to walk upon it.

BITUMINOUS COATING

The contractor shall coat the entire top surface of the slab with a bituminous curing compound, applied uniformly by means of an approved pressure spray distributor, at the rate of twenty (20) square yards per gallon of material. The material shall be so applied that the concrete surface is completely coated and sealed with a uniform, impervious film of bitumen at one application.

Application shall be made immediately after the concrete has been deposited and finished, and any surplus water that has collected on the surface thereof has disappeared, but before any marked dehydration of the concrete has taken place, or surface checking has started to occur.

After the surface has been coated, as specified, no further attention will be required, other than adequately protecting the concrete from traffic for the period of time required by the engineer.

BITUMINOUS CURING COMPOUND

The material shall have the following characteristics:

1. It shall be homogeneous and free from water.
2. The viscosity shall be between 60 and 150 (Sayboldt Furol) at 100° F.
3. When distilled (A.S.T.M., D-20-30) up to a temperature of 425° F. the total distillate shall not be less than 55 nor more than 60 percent by volume. The initial boiling point of the distillate shall not be under 220° F. and at least 45 percent of the total distillate shall have distilled over at 350° F. The residue poured from the flask immediately after the distillation shall have the following characteristics:
   - (a) It shall have a specific gravity not less than 0.90 at 77° F.
   - (b) It shall have a penetration (77° F. — 100 gm. — 5 sec.) of between 2 and 10.
   - (c) Its solubility in carbon bisulfide shall be at least 90%.
   - (d) Its softening point (B & R glycerin bath) shall be between 180° and 225° F.
   - (e) It shall show between 10 and 20 percent fixed carbon.
4. It shall be composed of mined or native asphalts containing filler.
5. It shall form an impervious protective film with one coat.

COLOR COAT

Within forty-eight (48) hours prior to opening the pavement to traffic the surface of the concrete slab shall be given a second coat of bituminous compound, of the same material heretofore specified for curing.

Application shall be made by means of an approved pressure distributor at the rate of twenty (20) square yards per gallon of material. The material shall be spread over the surface so as to give a uniform color coating.

Where necessary any structures, curbs, marking lanes or any other appurtenances shall be protected from staining by shields or other approved methods.

Over 25 million yards of Hunt Process curing throughout the United States is the best evidence of its efficiency and economy.

Comparison of Operations in Surface Curing Methods

Wet Earth Method	1—Cover concrete with burlap. 2—Water burlap for 24 hours. 3—Remove burlap. 4—Cover concrete with earth. 5—Wet earth daily. 6—Remove earth. 7—Clean pavement.
Ponding Method	1—Build earth dam. 2—Fill dam with water. 3—Renew water lost by evaporation and leakage and repair dam. 4—Remove dam. 5—Clean pavement.
Sodium Silicate or Calcium Chloride Methods	1—Cover concrete with burlap. 2—Water burlap for 24 hours. 3—Remove burlap. 4—Spread Calcium-Chloride or Sodium Silicate over slub. 5—If it rains within 24 hours, renew coating. 6—Sweep pavement.
Hay and Water Method	1—Cover concrete with burlap. 2—Water burlap for 24 hours. 3—Remove burlap. 4—Cover concrete with 6 inches of hay. 5—Water hay, and keep saturated for 10 days. 6—Remove wet hay. 7—Sweep pavement.
Ordinary Bituminous Method	1—Cover concrete with burlap. 2—Water burlap for 24 hours. 3—Remove burlap. 4—Spray concrete with bituminous mixture.
Hunt Process Method	**1—Spray Hunt Process on concrete directly behind the finishing machine.**